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(71) Applicant: MOTOROLA, INC. [US/US]; 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

(72) Inventors: DESNOYERS, Peter, Joseph; 162 Pleasant Street, Cambridge, MA 02139 (US). QURESHI, Shahid, Ul, Hao; 24 Indian Ridge Road, Natcik, MA 01760 (US).

(74) Agents: PARMELEE, Steven, G. et al.; Motorola Inc., Intellectual Property Depart./DJS, 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

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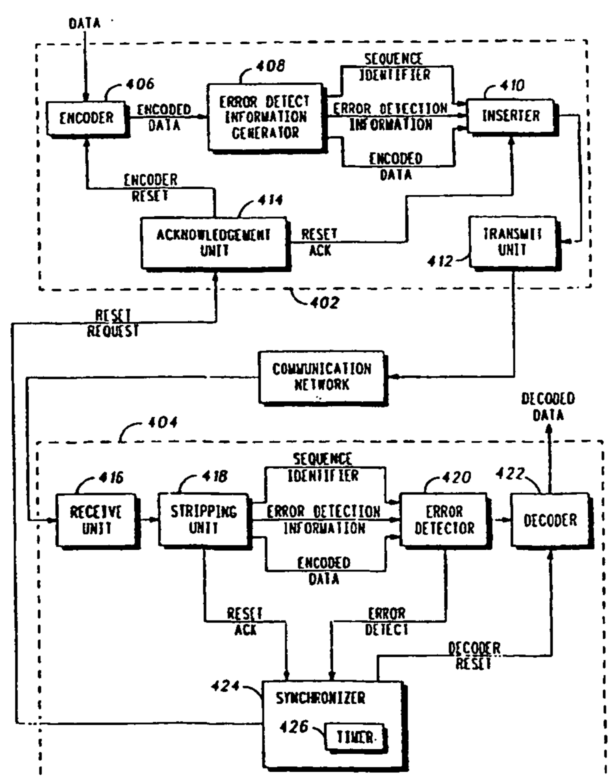
(57) Abstract

The method and system (400) synchronize an encoder of an encoder error synchronizer (402) and a decoder of a decoder error synchronizer (404) for data utilizing sequence indicators and error detection information added to the data before transmission. For example, compressed data may be organized into units, a sequence indicator and error detection information added to the compressed data unit (410) and the received units may be synchronized using the sequence indicators and error corrected using the error detection information.



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METHOD AND SYSTEM FOR SYNCHRONIZING ENCODERS AND DECODERS IN COMMUNICATION NETWORKS WHEN ERRORS ARE DETECTED

NETWORKS

Field of the Invention

This invention relates to communication systems and in particular to the synchronization of transmitted encoded data such as compressed data in communication networks.

Background

Digital systems typically communicate using packet-switched digital communication networks. The networks generally include a plurality of nodes that may transmit, receive or forward data. Data to be transmitted is typically organized into units such as frames or cells. The units are sent from one node to another either directly or utilizing one or more intermediate nodes. The communication channel established between edge nodes in the network is generally termed a virtual circuit.

When data that is sent through the network is compressed before transmittal, transmission efficiency through the network is increased. Typically, an encoder at a source node may compress data, which is then transmitted and decompressed at a destination node. However, when error(s) occur during transmission, synchronization between the encoder and the decoder is lost. There is a need for efficient synchronization of transmittal of data through a network.

Brief Descriptions of the Drawings

FIG. 1 is a block diagram of users groups connected to a communication network as is known in the art.

FIG. 2 is a flow chart of a first embodiment of steps in accordance with the method of the present invention.

FIG. 3 is a flow chart showing one embodiment of the step of synchronizing an encoder and a decoder when an error is detected (FIG. 2) with greater particularity.

FIG. 4 is a block diagram of a first embodiment of a system in accordance with the system of the present invention.

FIG. 5 is a flow chart of a second embodiment of steps in accordance with the method of the present invention.

Detailed Description of a Preferred Embodiment

FIG. 1, numeral 100, is a block diagram of users groups connected to a communication network as is known in the art. Typically, a first user group (102) is operably coupled to a first node (104) of a communication network (106), that is in turn coupled to other nodes (108, 110), and to a receiving node (112) for a second user group (114). Data is exchanged between the first user group and the second user group by transmittal between the first node and the receiving node via connected nodes of the communication network.

FIG. 2, numeral 200, is a flow chart of an embodiment of steps in accordance with the method of the present invention. The method synchronizes an encoder and decoder of a communication network upon detecting an error. The method

includes, for units of encoded data, the steps of: 1) adding to each unit of encoded data, error detection information based on a current unit and at least one previous unit to provide error detect units (202); 2) transmitting said error detect units across the communication network (204); 3) receiving the error detect units (206); 4) detecting error(s) utilizing the error detection information (208), and 5) synchronizing the encoder and decoder upon detecting error(s) (210).

In one embodiment the units of encoded data are frames of asynchronous transfer mode (ATM) cells that are transmitted across an ATM communication network. For example, a unit may be selected to be a data unit in an ISDN adaptation layer such as B-ISDN ATM Adaptation Layer 5 (AAL5) of CCITT recommendation I.363.

Error detection information is generally a code sequence added to said unit of encoded data subsequent to encoding the data such as a cyclic redundancy code (CRC), a code sequence other than a CRC wherein the code sequence is calculated from the encoded data, a code sequence other than a CRC wherein the code sequence is based on a size of the unit of encoded data, or a code sequence other than a CRC wherein the code sequence is based on the number of said data units since a previous reset. Thus, where a code sequence is based on a size of the unit of encoded data, for example, a code sequence may be based on a sequence number or running byte-count.

When encoding and decoding are performed on a sequence of data frames, the states of the encoder and decoder are often maintained between processing of successive frames without resetting at the beginning of each frame. Therefore, synchronization must be maintained from frame-to-frame. For example, if the communication network drops an entire frame

or mis-orders a sequence of frames, synchronization will be lost. Whereas typical CRCs are based entirely on only a single frame, they are only capable of detecting transmission errors which occur within that frame. They are insufficient for the purpose of detecting the type of error in which frames are lost entirely or mis-ordered. According to the technique of the present invention, for the purpose of detecting loss of synchronization, the error detection information must be based on the current encoded frame and on at least the previous encoded frame.

In one embodiment, the encoder responds to receipt of a reset request code sequence by resetting the encoder and generating a reset acknowledgement code sequence to the decoder. The decoder is reset when it receives the reset acknowledgment code sequence, thereby resynchronizing with the encoder. In this case, the decoder discards frames received after transmission of the reset request code sequence until the reset acknowledgement code sequence is received. In a second embodiment, it is unnecessary for the encoder to explicitly transmit a reset acknowledgement code sequence to the decoder. Instead, the decoder resets itself, including the decoder error detecting circuit at the beginning of each encoded frame until an encoded frame is received that passes error detection without an error. In this case, the decoder performs error detection, then discards frames received after transmission of the reset request code sequence until a frame passes error detection without an error. The first encoded frame that passes error detection in the decoder without an error is taken to be the first frame sent by the encoder following the reset of the encoder in response to the reset request code sequence; the encoder and the decoder are then said to be synchronized.

In one embodiment, each successive frame in the sequence of encoded frames is associated with the next value of a frame counter, called a sequence number. In another embodiment, each successive encoded data byte in the sequence of encoded bytes of encoded frames is associated with the next value of a byte counter, called a sequence number. The sequence number for a frame may be concatenated with the CRC for that frame to comprise the error detecting information for that frame. In another embodiment, the sequence number and the CRC are combined by adding them together to comprise the error detection information. In yet another embodiment, the error detection information is a CRC computed for the current frame, where unlike the common practice, the CRC is not reset to a fixed initial value at the beginning of the current frame, but instead the CRC is initialized to the value computed from the previous frame. These and other embodiments of the error detection information are chosen to be simple enough to minimize the cost of implementation, small enough to minimize the cost of transmission over the network, and are sufficiently unique to the particular encoded frame sequence to provide an acceptably high probability of detecting bit-errors and lost or misordered frames.

The communication network includes a plurality of nodes arranged so that a plurality of paths exist among at least some nodes between which said method is practiced. Typically, at least one node may communicate with more than one node at a time. Generally, encoded data may be selected to be compressed data.

Synchronizing the encoder and decoder may be selected to further include: (1) upon detecting an error at decoder, transmitting a reset request code sequence over a reverse channel upon said detecting of error(s) to the encoder, and

where the encoder transmits an acknowledgment code sequence over said communication network to acknowledge reception of said reset request code sequence, one of: a) where the acknowledgment code sequence is received, resetting the decoder, and b) where there is a failure of the acknowledgment code sequence to be received, the decoder transmitting a further reset request code sequence to the encoder, and alternatively, 2) where the decoder resets the timer upon a received unit successfully passing error detection.

FIG. 3, numeral 300, is a flow chart showing one embodiment of the step of synchronizing an encoder and a decoder when an error is detected (FIG. 2) with greater particularity. Each step of synchronizing the encoder and decoder when an error is detected may include (1) detecting of error(s) at the decoder (302), (2) transmitting a reset request code sequence to the encoder, and where selected, setting a timer (304), (3) the encoder's receiving the reset request code sequence (306), (4) the encoder's resetting and generating a reset acknowledgment (308), (5) the decoder's waiting (310) for one of: expiration of the timer and receiving the reset acknowledgment, (6) upon expiration of the time without receiving the reset acknowledgment, recycling to sending the reset request and starting the timer (304), and, (7) upon receiving the reset acknowledgment, resetting the decoder (312). The reset request code sequence initiates resetting of the encoder and sending acknowledgment (ACK) of receipt of the request acknowledgment code sequence to the decoder. Where a timer has been set, the decoder determines whether the timer has expired without the decoder's receiving an acknowledgment from the encoder (306), and where the timer is expired without an acknowledgment, the step of transmitting the reset request to the encoder is repeated. When the timer is unexpired, the decoder determines whether a

reset acknowledgment has been received from the encoder (308). Where there is a failure of the reset acknowledgment to be received, the method recycles to the step of transmitting the reset request to the encoder (304). Where the reset acknowledgment is received, the decoder is reset (310).

Thus, upon the decoder's detecting an error, the method may include the decoder's transmitting a reset request to the encoder, and where the reset request code sequence is received at the encoder, resetting the encoder. Here, each step of synchronizing the encoder and decoder further includes one of: (1) where the encoder transmits an acknowledgment code sequence over said communication network to acknowledge reception of said reset request code sequence and the acknowledgment code sequence is received, resetting the decoder such that the decoder is synchronized with the encoder, and (2) where the decoder is reset upon the decoding of each encoded data unit until a received unit successfully passed error detection. In addition, said step of synchronizing the encoder and decoder upon detecting error(s) may be selected to further include one of: (1) transmitting a second reset request code sequence over a reverse channel upon failure to receive said acknowledgment code sequence upon an expiration of a timer, and (2) transmitting a second reset request code sequence over said reverse channel upon failure of at least one received unit to successfully pass error detection upon an expiration of said timer. Thus, transmission of said second reset request may further include iteratively restarting said timer and transmitting subsequent reset request code sequences when said timer expires until the encoder and decoder are synchronized.

The communication network typically further includes a plurality of nodes arranged such that a plurality of paths exist between at least some nodes between which said method is

practiced, and wherein at least one node may communicate with more than one node at a time using different encoding methods to communicate with at least two different nodes, and wherein the timer is shared by said nodes using different encoding methods.

Where said encoded data includes compressed data and said step of synchronizing the error detect units includes resynchronizing a transmitter at which insertion and transmitting are performed and a receiver at which receiving the error detect units, the method may include detecting error(s) utilizing the error detection information and the sequence indicators.

FIG. 4, numeral 400, is a block diagram of a first embodiment of a system in accordance with the system of the present invention. The system synchronizes an encoder of an encoder error synchronizer (402) and a decoder of a decoder error synchronizer (404) for encoded data transmitted across a communication network upon error detection. The encoder error synchronizer (402) is operably coupled to receive data and a reset request from the decoder error synchronizer (404), and is used for transmitting encoded data having error detection information and for, upon receiving the reset request, resetting the encoder. The decoder error synchronizer (404) is operably coupled across the communication network to receive the encoded data, detecting error(s), and, upon detecting error(s), to send a reset request to the encoder error synchronizer (402).

Typically, the encoder error synchronizer (402) includes: an encoder (406) that is operably coupled to receive data and to an to an acknowledgment unit and is used for encoding data and, upon receiving an encoder reset signal from an acknowledgment unit (414), resetting; an error detect

information generator (408) that is operably coupled to the encoder (406) and is used for receiving the encoded data and for organizing the data into units of predetermined size(s) and providing sequence identifiers for said units of the encoded data, providing error detection information, and for providing the encoded data to an inserter (410); the inserter (410), that is operably coupled to receive the encoded data, the sequence indicators and error detection information and is used for adding to each unit of encoded data a sequence indicator and error detection information to provide error detect units; a transmission unit (412) that is operably coupled to the inserter (410) and is used for transmitting said error detect units across the communication network; and the acknowledgment unit (414) that is operably coupled to receive a reset request from the decoder error synchronizer (404) and is used for, upon receiving the reset request signal, sending a reset signal to the encoder (406) and a reset acknowledgment signal to the inserter (410).

The decoder error synchronizer (404) typically includes: a receiving unit (416) that is operably coupled to the encoder error synchronizer (402), typically by means of a communication network, and is used for receiving the error detect units; a stripping unit (418) that is operably coupled to the receiving unit (416) and is used for providing the sequence identifiers, the error detection information and encoded data for each error detect unit and for transmitting a received reset acknowledgment to a synchronizer (424); an error detector (420) that is operably coupled to the stripping unit (418) and is used for detecting error(s) utilizing the error detection information and the sequence indicators and for providing an error detect signal to the synchronizer (424); a decoder (422) that is operably coupled to the error detector (420) and to the synchronizer (424) and is used for decoding data and resetting upon receiving a reset signal from the

synchronizer; and the synchronizer (424) that is operably coupled to the stripping unit (418) and to the error detector (420) for sending the reset signal to the decoder (422) and for sending a reset request to the encoder error synchronizer (402) upon receiving the error detect signal from the error detector (420).

The units of encoded data are typically frames of asynchronous transfer mode (ATM) cells and the communication network is an ATM network. .

Error detection information is generally a code sequence added to said unit of encoded data subsequent to encoding the data such as a cyclic redundancy code (CRC), a code sequence other than a CRC wherein the code sequence is calculated from the encoded data, a code sequence other than a CRC wherein the code sequence is based on a size of the unit of encoded data, or a code sequence other than a CRC wherein the code sequence is based on the number of said data units since a previous reset. Thus, where a code sequence is based on a size of the unit of encoded data, for example, a code sequence may be based on a sequence number or running byte-count.

When encoding and decoding are performed on a sequence of data frames, the states of the encoder and decoder are often maintained between processing of successive frames without resetting at the beginning of each frame. Therefore, synchronization must be maintained from frame-to-frame. For example, if the communication network drops an entire frame or mis-orders a sequence of frames, synchronization will be lost. Whereas typical CRCs are based entirely on only a single frame, they are only capable of detecting transmission errors which occur within that frame. They are insufficient for the purpose of detecting the type of error in which frames

are lost entirely or mis-ordered. According to the technique of the present invention, for the purpose of detecting loss of synchronization, the error detection information must be based on the current encoded frame and on at least the previous encoded frame.

In one embodiment, each successive frame in the sequence of encoded frames is associated with the next value of a frame counter, called a sequence number. In another embodiment, each successive encoded data byte in the sequence of encoded bytes of encoded frames is associated with the next value of a byte counter, called a sequence number. The sequence number for a frame may be concatenated with the CRC for that frame to comprise the error detecting information for that frame. In another embodiment, the sequence number and the CRC are combined by adding them together to comprise the error detection information. In yet another embodiment, the error detection information is a CRC computed for the current frame, where unlike the common practice, the CRC is not reset to a fixed initial value at the beginning of the current frame, but instead the CRC is initialized to the value computed from the previous frame. These and other embodiments of the error detection information are chosen to be simple enough to minimize the cost of implementation, small enough to minimize the cost of transmission over the network, and are sufficiently unique to the particular encoded frame sequence to provide an acceptably high probability of detecting bit-errors and lost or misordered frames.

The communication network generally includes a plurality of nodes so arranged that a plurality of paths exist between at least some nodes between which said system is

practiced. At least one node may communicate with more than one node at a time.

The encoded data is generally compressed data.

The synchronizer may be selected to further include a timer (426) that is operably coupled to the error detector (420) and is used for starting timing upon said detecting of errors and for transmitting a second reset request code sequence over said reverse channel upon failure to receive said request acknowledgment code sequence upon an expiration of said timer.

The communication network may be selected to further include a plurality of nodes arranged such that a plurality of paths exist between at least some nodes between which said system is practiced, and wherein at least one node may communicate with more than one node at a time using different encoding methods to communicate with at least two different nodes, and wherein the timer is shared by said nodes using different encoding methods.

FIG. 5, numeral 500, is a flow chart of a second embodiment of steps in accordance with the method of the present invention. The method synchronizes an encoder and decoder of a communication network upon detecting an error. The method includes, for units of encoded data, the steps of: 1) adding to each unit of encoded data, error detection information based on a predetermined combination of units of encoded data to provide error detect units (502); 2) transmitting said error detect units across the communication network (504); 3) receiving the error detect units (506); 4) detecting error(s) utilizing the error detection information (508), and 5) synchronizing the encoder and decoder upon detecting error(s) (510). The predetermined combination of

units of encoded data may be selected, for example, to be a present unit of encoded data and a preselected number of prior units of encoded data.

As described for FIG. 3, the units of encoded data may be selected to be frames of asynchronous transfer mode (ATM) cells and the frames of ATM cells may be transmitted across an ATM communication network.

The error detection information typically is a code sequence added to said unit of encoded data subsequent to encoding the data wherein the code sequence is one of: a cyclic redundancy code (CRC), and a code sequence other than a CRC wherein the code sequence is calculated from the encoded data in accordance with a predetermined scheme.

Further description of particularities of the method of FIG. 6 follows the description of FIG. 3.

Although exemplary embodiments are described above, it will be obvious to those skilled in the art that many alterations and modifications may be made without departing from the invention. Accordingly, it is intended that all such alterations and modifications be included within the spirit and scope of the invention as defined in the appended claims.

We claim:

1. A method for synchronizing an encoder and a decoder for transmission of units of encoded data across a communication network, said method comprising the steps of:

1A) adding to each said unit error detection information based on a current and at least one previous unit to provide error detect units,

1B) transmitting said error detect units across the communication network,

1C) receiving the error detect units,

1D) detecting error(s) utilizing the error detection information, and

1E) synchronizing the encoder and decoder upon error detection.

2. The method of claim 1 wherein at least one of 2A-2E:

2A) the units of encoded data are frames of asynchronous transfer mode (ATM) cells, and where selected, wherein the frames of ATM cells are transmitted across an ATM communication network;

2B) said error detection information is a code sequence added to said unit of encoded data subsequent to encoding the data, and where selected, wherein the code sequence is one of:

2B1) a cyclic redundancy code (CRC),

2B2) a code sequence other than a CRC wherein the code sequence is calculated from the encoded data,

2B3) a code sequence other than a CRC wherein the code sequence is based on a size of the unit of encoded data, and

2B4) a code sequence other than a CRC wherein the code sequence is based on the number of said data units since a previous reset;

2C) the communication network includes a plurality of nodes so arranged that a plurality of paths exist among at least some nodes between which said method is practiced, and where selected, wherein at least one node may communicate with more than one node at a time;

2D) the encoded data comprises compressed data; and

2E) said encoded data comprises compressed data, and wherein said step of synchronizing the encoder and decoder includes resynchronizing a transmitter at which steps 1A-1B are performed and a receiver at which steps 1C-1E are performed.

3. The method of claim 1 wherein upon the decoder's detecting an error, the decoder's transmitting a reset request to the encoder, and

where the reset request code sequence is received at the encoder, resetting the encoder, and

where each step of synchronizing the encoder and decoder further includes one of 3A-3B:

3A) where the encoder transmits an acknowledgment code sequence over said communication network to acknowledge reception of said reset request code sequence and the acknowledgment code sequence is received, resetting the decoder such that the decoder is synchronized with the encoder, and

3B) where the decoder is reset upon the decoding of each encoded data unit until a received unit successfully passed error detection,

and where selected,

3C) wherein said step of synchronizing the encoder and decoder upon detecting error(s) further includes one of 3C1 and 3C2:

3C1) transmitting a second reset request code sequence over a reverse channel upon failure to receive said acknowledgment code sequence upon an expiration of a timer, and

3C2) transmitting a second reset request code sequence over said reverse channel upon failure of at least one received unit to successfully pass error detection upon an expiration of said timer;

and where further selected,

3D) where transmission of said second reset request further includes iteratively restarting said timer and transmitting subsequent reset request code sequences when said timer expires until the encoder and decoder are synchronized,

and where further selected,

3E) wherein the communication network further includes a plurality of nodes arranged such that a plurality of paths exist between at least some nodes between which said

method is practiced, and wherein at least one node may communicate with more than one node at a time using different encoding methods to communicate with at least two different nodes, and wherein the timer is shared by the node using different encoding methods.

4. A system for synchronizing an encoder of an encoder error synchronizer and a decoder of a decoder error synchronizer upon detection of error(s) in transmission of units of encoded data across a communication network, said system comprising:

4A) an encoder error synchronizer, operably coupled to receive data and a reset request from the decoder error synchronizer, for transmitting encoded data having error detection information and for, upon receiving the reset request, resetting the encoder, and

4B) a decoder error synchronizer, operably coupled to receive the encoded data, detecting error(s), and, upon detecting error(s), sending a reset request to the encoder error synchronizer.

5. The system of claim 4, wherein at least one of 5A-5F:

5A) the encoder error synchronizer comprises 5A1-5A5:

5A1) an encoder, operably coupled to receive data and to an to an acknowledgment unit, for encoding data and, upon receiving an encoder reset signal from the acknowledgment unit, resetting,

5A2) an error detect information generator, operably coupled to the encoder, for receiving the encoded data and for organizing the data into units of predetermined size(s) and providing sequence identifiers for said units of the encoded data, providing error detection information, and for providing the encoded data to an inserter,

5A3) the inserter, operably coupled to receive the encoded data, the sequence indicators and error detection information, for adding to each unit of encoded data a sequence indicator and error detection information to provide error detect units,

5A4) a transmission unit, operably coupled to the inserter, for transmitting said error detect units across the communication network, and

5A5) the acknowledgment unit, operably coupled to receive a reset request from the decoder error synchronizer, for, upon receiving the reset request signal, sending a reset signal to the encoder and a reset acknowledgment signal to the inserter;

5B) the units of encoded data are frames of asynchronous transfer mode (ATM) cells;

5C) the communication network is an ATM network;

5D) said error detection information is a code sequence added to said unit of encoded data subsequent to encoding the data, and where selected, wherein the code sequence is one of 5D1-5D4:

5D1) a cyclic redundancy code (CRC),

5D2) a code sequence other than a CRC wherein the code sequence is calculated from the encoded data,

5D3) a code sequence other than a CRC wherein the code sequence is based on a size of the unit of encoded data, and

5D4) a code sequence other than a CRC wherein the code sequence is based on the number of said data units since a previous reset;

5E) the communication network includes a plurality of nodes so arranged that a plurality of paths exist between at least some nodes between which said system is practiced, and where selected, wherein at least one node may communicate with more than one node at a time;

5F) the encoded data comprises compressed data.

6. The system of claim 4 wherein the decoder error synchronizer comprises 6A-6E:

6A) a receiving unit, operably coupled to the encoder error synchronizer, for receiving the error detect units,

6B) a stripping unit, operably coupled to the receiving unit, for providing the sequence identifiers, the error detection information and encoded data for each error detect unit and for transmitting a received reset acknowledgment to a synchronizer,

6C) an error detector, operably coupled to the stripping unit, for detecting error(s) utilizing the error detection information and the sequence indicators and for providing an error detect signal to the synchronizer,

6D) a decoder, operably coupled to the error detector and to the synchronizer, for decoding data and resetting upon receiving a reset signal from the synchronizer, and

6E) the synchronizer, operably coupled to the stripping unit and to the error detector, for sending the reset signal to the decoder and for sending a reset request to the

encoder error synchronizer on a reverse channel upon receiving the error detect signal from the error detector, and where selected, wherein the synchronizer further includes a timer, operably coupled to the error and sequence detector, for starting timing upon said detecting of errors and for transmitting a second reset request code sequence over said reverse channel upon failure to receive said request acknowledgment code sequence upon an expiration of said timer, and where further selected, wherein the communication network further includes a plurality of nodes arranged such that a plurality of paths exist between at least some nodes between which said system is practiced, and wherein at least one node may communicate with more than one node at a time using different encoding methods to communicate with at least two different nodes, and wherein the timer is shared by said nodes using different encoding methods.

7. A method for synchronizing an encoder and a decoder for transmission of predetermined units of data across a communication network, said method comprising the steps of:

7A) adding to each unit of encoded data, error detection information based on a predetermined combination of units of encoded data to provide error detect units,

7B) transmitting said error detect units across the communication network,

7C) receiving the error detect units,

7D) detecting error(s) utilizing the error detection information, and

7E) synchronizing the encoder and decoder upon detecting error(s).

8. The method of claim 7 wherein at least one of 8A-8F:

8A) the units of encoded data are frames of asynchronous transfer mode (ATM) cells;

8B) the frames of ATM cells are transmitted across an ATM communication network;

8C) said error detection information is a code sequence added to said unit of encoded data subsequent to encoding the data;

8D) the code sequence is one of 8D1-8D4:

8D1) a cyclic redundancy code (CRC),

8D2) a code sequence other than a CRC wherein the code sequence is calculated from the encoded data,

8D3) a code sequence other than a CRC wherein the code sequence is based on a size of the unit of encoded data, and

8D4) a code sequence other than a CRC wherein the code sequence is based on the number of said data units since a previous reset;

8E) the encoded data comprises compressed data; and

8F) the communication network further includes a plurality of nodes arranged such that a plurality of paths exist between at least some nodes between which said method is practiced, and wherein at least one node may communicate with more than one node at a time using different encoding methods to communicate with at least two different nodes, and wherein the timer is shared by the node using different encoding methods.

9. The method of claim 7 wherein the communication network includes a plurality of nodes so arranged that a plurality of paths exist among at least some nodes between which said method is practiced, and where selected, wherein at least one node may communicate with more than one node at a time.

10. The method of claim 7 wherein upon the decoder's detecting an error, the decoder's transmitting a reset request to the encoder, and

where the reset request code sequence is received at the encoder, resetting the encoder, and

where each step of synchronizing the encoder and decoder further includes one of:

10A) where the encoder transmits an acknowledgment code sequence over said communication network to acknowledge reception of said reset request code sequence and the acknowledgment code sequence is received, resetting the decoder such that the decoder is synchronized with the encoder, and

10B) where the decoder is reset upon the decoding of each encoded data unit until a received unit successfully passed error detection;

and where selected,

wherein said step of synchronizing the encoder and decoder upon detecting error(s) further includes one of 10C and 10D:

10C) transmitting a second reset request code sequence over a reverse channel upon failure to receive said acknowledgment code sequence upon an expiration of a timer, and

10D) transmitting a second reset request code sequence over said reverse channel upon failure of at least one received unit to successfully pass error detection upon an expiration of said timer;

and where further selected, where transmission of said second reset request further includes iteratively restarting said timer and transmitting subsequent reset request code sequences when said timer expires until the encoder and decoder are synchronized.

AMENDED CLAIMS

[received by the International Bureau on 03 February 1995 (03.02.95); original claims 1, 4, 7 amended; remaining claims unchanged (9 pages)]

1. (Amended) A method for synchronizing an encoder and a decoder for transmission of units of encoded data across a communication network, said method comprising the steps of:

1A) adding to each said unit error detection information based on a current and at least one previous unit to provide error detect units,

1B) transmitting said error detect units across the communication network,

1C) receiving the error detect units,

1D) detecting error(s) utilizing the error detection information, and

1E) synchronizing the encoder and decoder upon error detection,

1F) wherein said error detection information is a code sequence added to said unit of encoded data subsequent to encoding the data, and where selected, wherein the code sequence is one of:

1F1) a cyclic redundancy code (CRC),

1F2) a code sequence other than a CRC wherein the code sequence is calculated from the encoded data,

1F3) a code sequence other than a CRC wherein the code sequence is based on a size of the unit of encoded data, and

1F4) a code sequence other than a CRC wherein the code sequence is based on the number of said data units since a previous reset;

and

1G) the communication network includes a plurality of nodes so arranged that a plurality of paths exist among at least some nodes between which said method is practiced, and where selected, wherein at least one node may communicate with more than one node at a time;

1H) the encoded data comprises compressed data;

and

1I) said encoded data comprises compressed data, and wherein said step of synchronizing the encoder and decoder includes resynchronizing a transmitter at which steps 1A-1B are performed and a receiver at which steps 1C-1E are performed, and

1J) wherein upon the decoder's detecting an error, the decoder's transmitting a reset request to the encoder, and

where the reset request code sequence is received at the encoder, resetting the encoder, and

where each step of synchronizing the encoder and decoder further includes one of 1J1-1J2:

1J1) where the encoder transmits an acknowledgment code sequence over said communication network to acknowledge reception of said reset request code sequence and the acknowledgment code sequence is received, resetting the decoder such that the decoder is synchronized with the encoder, and

1J2) where the decoder is reset upon the decoding of each encoded data unit until a received unit successfully passed error detection.

2. The method of claim 1 wherein at least one of 2A-2D:

2A) the units of encoded data are frames of asynchronous transfer mode (ATM) cells, and where selected, wherein the frames of ATM cells are transmitted across an ATM communication network;

2B) the communication network includes a plurality of nodes so arranged that a plurality of paths exist among at least some nodes between which said method is practiced, and where selected, wherein at least one node may communicate with more than one node at a time;

2C) the encoded data comprises compressed data; and

2D) said encoded data comprises compressed data, and wherein said step of synchronizing the encoder and decoder includes resynchronizing a transmitter at which steps 1A-1B are performed and a receiver at which steps 1C-1E are performed.

3. The method of claim 1

3A) wherein said step of synchronizing the encoder and decoder upon detecting error(s) further includes one of 3C1 and 3C2:

3A1) transmitting a second reset request code sequence over a reverse channel upon failure to receive said acknowledgment code sequence upon an expiration of a timer, and

3A2) transmitting a second reset request code sequence over said reverse channel upon failure of at least one received unit to successfully pass error detection upon an expiration of said timer;

and where further selected,

3B) where transmission of said second reset request further includes iteratively restarting said timer and transmitting subsequent reset request code sequences when said timer expires until the encoder and decoder are synchronized, and where further selected,

3C) wherein the communication network further includes a plurality of nodes arranged such that a plurality of paths exist between at least some nodes between which said method is practiced, and wherein at least one node may communicate with more than one node at a time using different encoding methods to communicate with at least two different nodes, and wherein the timer is shared by the node using different encoding methods.

4. (Amended) A system for synchronizing an encoder of an encoder error synchronizer and a decoder of a decoder error synchronizer upon detection of error(s) in transmission of units of encoded data across a communication network, said system comprising:

4A) an encoder error synchronizer, operably coupled to receive data and a reset request from the decoder error synchronizer, for transmitting encoded data having error detection information and for, upon receiving the reset request, resetting the encoder, and

4B) a decoder error synchronizer, operably coupled to receive the encoded data, detecting error(s), and, upon detecting error(s), sending a reset request to the encoder error synchronizer,

and wherein at least one of 4C-4D:

4C) the encoder error synchronizer comprises 4C1-4C5:

4C1) an encoder, operably coupled to receive data and to an to an acknowledgment unit, for encoding data and, upon receiving an encoder reset signal from the acknowledgment unit, resetting,

4C2) an error detect information generator, operably coupled to the encoder, for receiving the encoded data and for organizing the data into units of predetermined size(s) and providing sequence identifiers for said units of the encoded data, providing error detection information, and for providing the encoded data to an inserter,

4C3) the inserter, operably coupled to receive the encoded data, the sequence indicators and error detection information, for adding to each unit of encoded data a sequence indicator and error detection information to provide error detect units,

4C4) a transmission unit, operably coupled to the inserter, for transmitting said error detect units across the communication network, and

4C5) the acknowledgment unit, operably coupled to receive a reset request from the decoder error synchronizer, for, upon receiving the reset request signal, sending a reset signal to the encoder and a reset acknowledgment signal to the inserter;

4D) said error detection information is a code sequence added to said unit of encoded data subsequent to encoding the data, and where selected, wherein the code sequence is one of 4D1-4D4:

4D1) a cyclic redundancy code (CRC),

4D2) a code sequence other than a CRC wherein the code sequence is calculated from the encoded data,

4D3) a code sequence other than a CRC wherein the code sequence is based on a size of the unit of encoded data, and

4D4) a code sequence other than a CRC wherein the code sequence is based on the number of said data units since a previous reset.

5. The system of claim 4, wherein at least one of 5A-5D:

5A) the units of encoded data are frames of asynchronous transfer mode (ATM) cells;

5B) the communication network is an ATM network;

5C) the communication network includes a plurality of nodes so arranged that a plurality of paths exist between at least some nodes between which said system is practiced, and where selected, wherein at least one node may communicate with more than one node at a time;

5D) the encoded data comprises compressed data.

6. The system of claim 4 wherein the decoder error synchronizer comprises 6A-6E:

6A) a receiving unit, operably coupled to the encoder error synchronizer, for receiving the error detect units,

6B) a stripping unit, operably coupled to the receiving unit, for providing the sequence identifiers, the error detection information and encoded data for each error detect unit and for transmitting a received reset acknowledgment to a synchronizer,

6C) an error detector, operably coupled to the stripping unit, for detecting error(s) utilizing the error detection information and the sequence indicators and for providing an error detect signal to the synchronizer,

6D) a decoder, operably coupled to the error detector and to the synchronizer, for decoding data and resetting upon receiving a reset signal from the synchronizer, and

6E) the synchronizer, operably coupled to the stripping unit and to the error detector, for sending the reset signal to the decoder and for sending a reset request to the encoder error synchronizer on a reverse channel upon receiving the error detect signal from the error detector, and where selected, wherein the synchronizer further includes a timer, operably coupled to the error and sequence detector, for starting timing upon said detecting of errors and for transmitting a second reset request code sequence over said reverse channel upon failure to receive said request acknowledgment code sequence upon an expiration of said timer, and where further selected, wherein the communication network further includes a plurality of nodes arranged such that a plurality of paths exist between at least some nodes between which said system is practiced, and wherein

at least one node may communicate with more than one node at a time using different encoding methods to communicate with at least two different nodes, and wherein the timer is shared by said nodes using different encoding methods.

7. (Amended) A method for synchronizing an encoder and a decoder for transmission of predetermined units of data across a communication network, said method comprising the steps of:

7A) adding to each unit of encoded data, error detection information based on a predetermined combination of units of encoded data to provide error detect units,

7B) transmitting said error detect units across the communication network,

7C) receiving the error detect units,

7D) detecting error(s) utilizing the error detection information, and

7E) synchronizing the encoder and decoder upon detecting error(s),

wherein said error detection information is a code sequence added to said unit of encoded data subsequent to encoding the data;

and wherein upon the decoder's detecting an error, the decoder's transmitting a reset request to the encoder, and

where the reset request code sequence is received at the encoder, resetting the encoder, and

where each step of synchronizing the encoder and decoder further includes one of:

7F) where the encoder transmits an acknowledgment code sequence over said communication network to acknowledge reception of said reset request code sequence and the acknowledgment code sequence is received, resetting the decoder such that the decoder is synchronized with the encoder, and

7G) where the decoder is reset upon the decoding of each encoded data unit until a received unit successfully passed error detection;

and where selected,

wherein said step of synchronizing the encoder and decoder upon detecting error(s) further includes one of 7H and 7I:

7H) transmitting a second reset request code sequence over a reverse channel upon failure to receive said acknowledgment code sequence upon an expiration of a timer, and

7I) transmitting a second reset request code sequence over said reverse channel upon failure of at least one received unit to successfully pass error detection upon an expiration of said timer;

and where further selected, where transmission of said second reset request further includes iteratively restarting said timer and transmitting subsequent reset request code sequences when said timer expires until the encoder and decoder are synchronized.

8. The method of claim 7 wherein at least one of 8A-8F:

8A) the units of encoded data are frames of asynchronous transfer mode (ATM) cells;

8B) the frames of ATM cells are transmitted across an ATM communication network;

8C) the code sequence is one of 8C1-8C4:

8C1) a cyclic redundancy code (CRC),

8C2) a code sequence other than a CRC wherein the code sequence is calculated from the encoded data,

8C3) a code sequence other than a CRC wherein the code sequence is based on a size of the unit of encoded data, and

8C4) a code sequence other than a CRC wherein the code sequence is based on the number of said data units since a previous reset;

8D) the encoded data comprises compressed data; and

8E) the communication network further includes a plurality of nodes arranged such that a plurality of paths exist between at least some nodes between which said method is practiced, and wherein at least one node may communicate with more than one node at a time using different encoding methods to communicate with at least two different nodes, and wherein the timer is shared by the node using different encoding methods.

9. The method of claim 7 wherein the communication network includes a plurality of nodes so arranged that a plurality of paths exist among at least some nodes between which said method is practiced, and where selected, wherein at least one node may communicate with more than one node at a time.

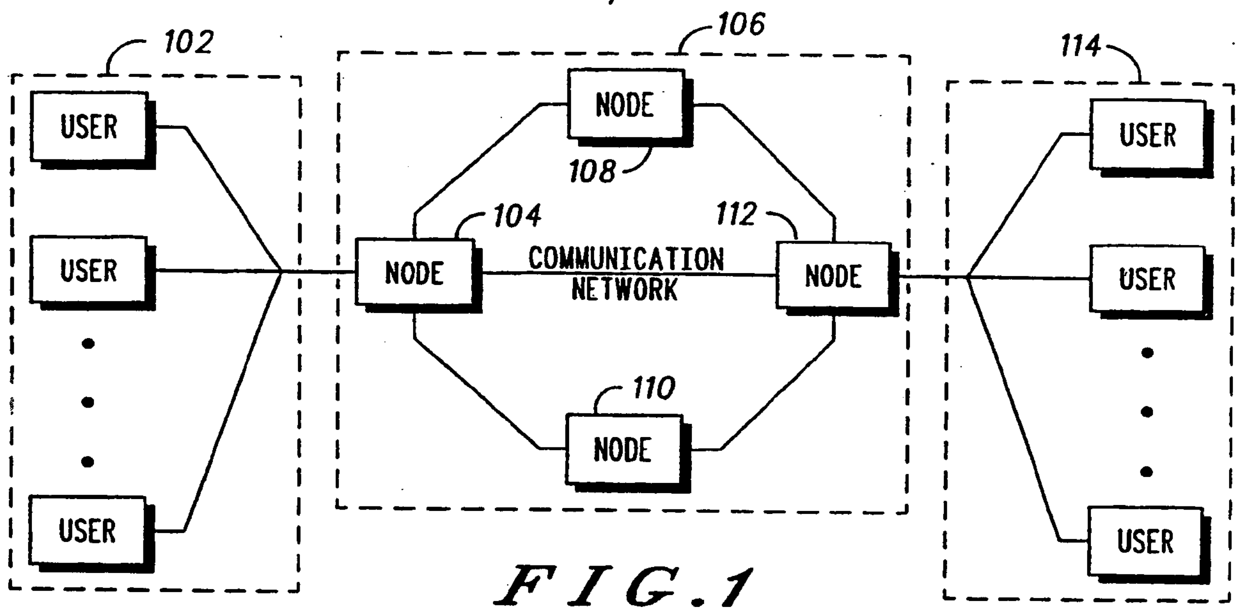


FIG.1
100
—PRIOR ART—

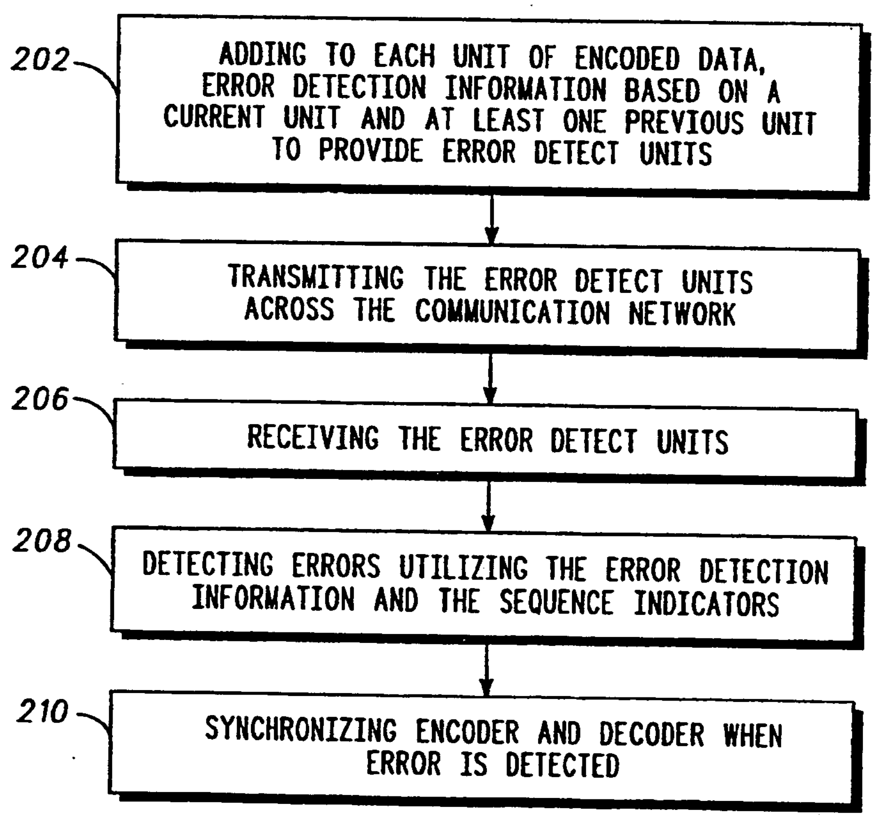


FIG.2
200

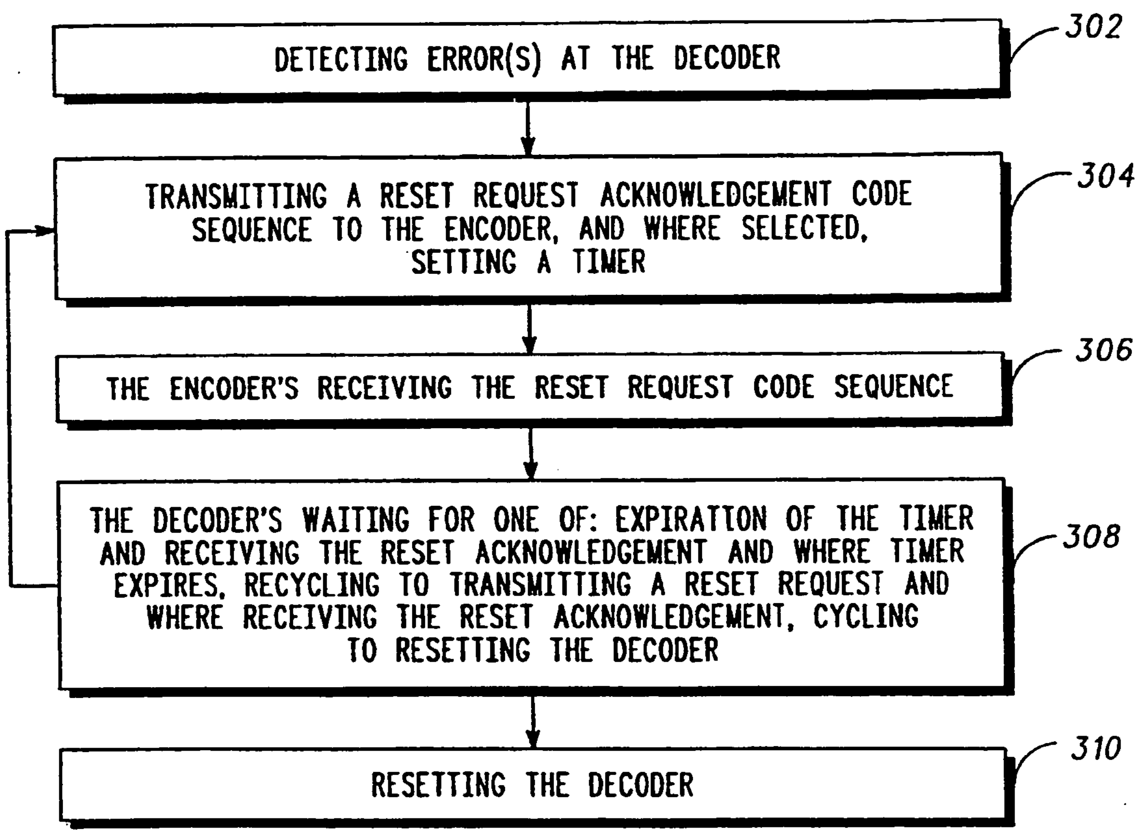
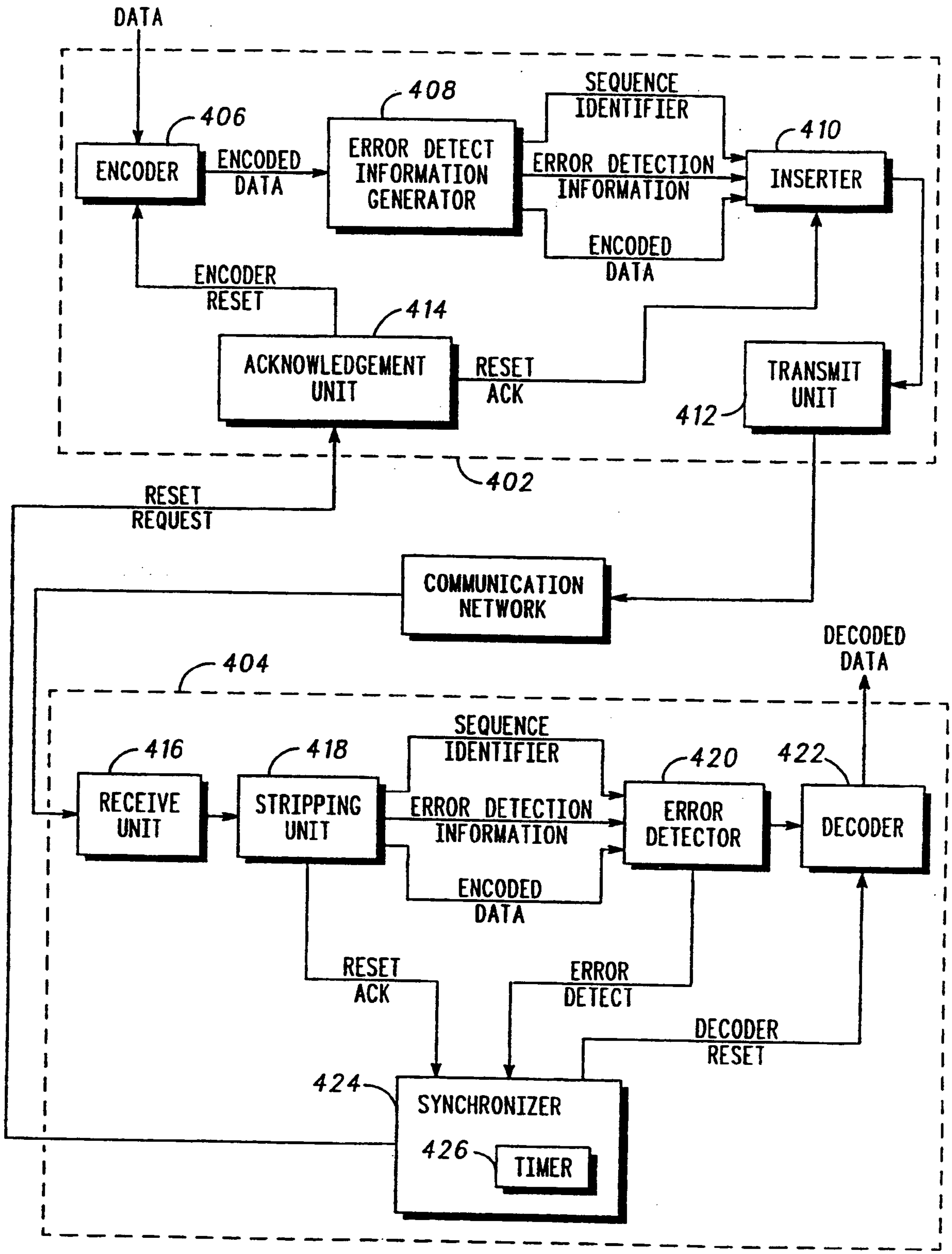

DETECTING ERROR(S) AT THE DECODER
302
TRANSMITTING A RESET REQUEST ACKNOWLEDGEMENT CODE SEQUENCE TO THE ENCODER, AND WHERE SELECTED, SETTING A TIMER
304
THE ENCODER'S RECEIVING THE RESET REQUEST CODE SEQUENCE
306
THE DECODER'S WAITING FOR ONE OF: EXPIRATION OF THE TIMER AND RECEIVING THE RESET ACKNOWLEDGEMENT AND WHERE TIMER EXPIRES, RECYCLING TO TRANSMITTING A RESET REQUEST AND WHERE RECEIVING THE RESET ACKNOWLEDGEMENT, CYCLING TO RESETTING THE DECODER
308
RESETTING THE DECODER
310

FIG. 3

300



DATA
406
ENCODER
ENCODED DATA
408
ERROR DETECT INFORMATION GENERATOR
SEQUENCE IDENTIFIER
ERROR DETECTION INFORMATION
ENCODED DATA
410
INSERTER
ENCODER RESET
414
ACKNOWLEDGEMENT UNIT
RESET ACK
TRANSMIT UNIT
412
402
RESET REQUEST
COMMUNICATION NETWORK
DECODED DATA
404
416
RECEIVE UNIT
418
STRIPPING UNIT
SEQUENCE IDENTIFIER
ERROR DETECTION INFORMATION
ENCODED DATA
420
ERROR DETECTOR
422
DECODER
RESET ACK
ERROR DETECT
DECODER RESET
424
SYNCHRONIZER
426
TIMER

FIG. 4
400

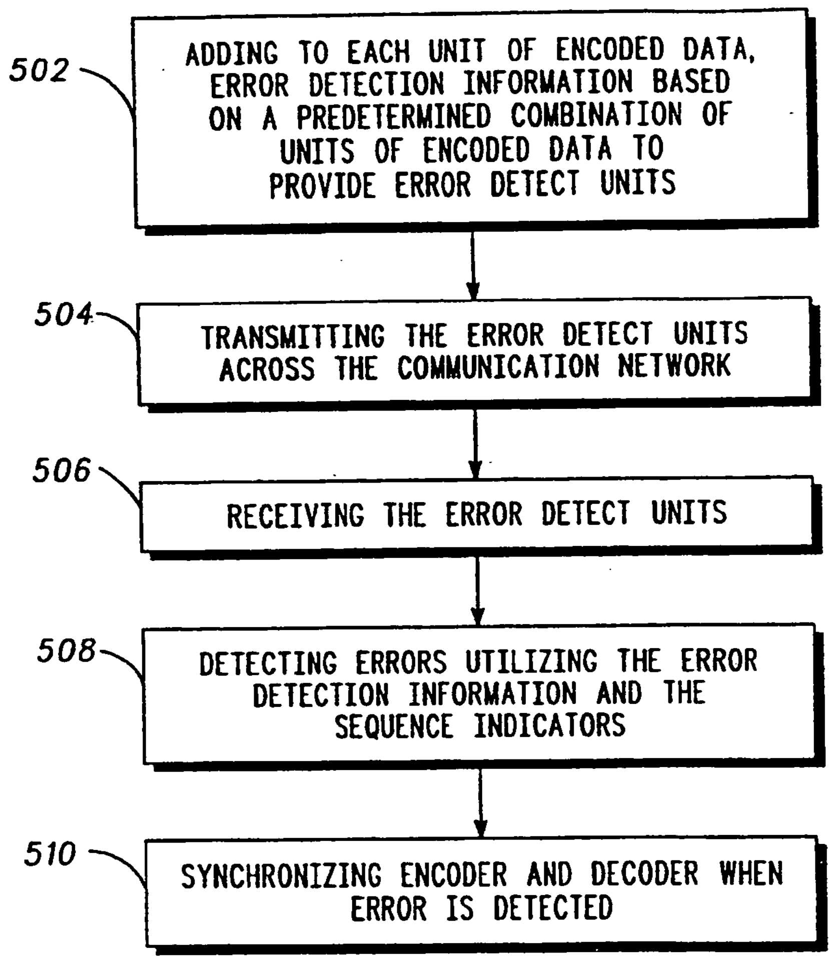

502
ADDING TO EACH UNIT OF ENCODED DATA, ERROR DETECTION INFORMATION BASED ON A PREDETERMINED COMBINATION OF UNITS OF ENCODED DATA TO PROVIDE ERROR DETECT UNITS
504
TRANSMITTING THE ERROR DETECT UNITS ACROSS THE COMMUNICATION NETWORK
506
RECEIVING THE ERROR DETECT UNITS
508
DETECTING ERRORS UTILIZING THE ERROR DETECTION INFORMATION AND THE SEQUENCE INDICATORS
510
SYNCHRONIZING ENCODER AND DECODER WHEN ERROR IS DETECTED

FIG. 5

500

dm

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/12033

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G06F 11/10; H04L 12/56
US CL :371/42; 370/94.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 371/42, 32, 33, 47.1, 37.1; 370/94.1, 94.2, 94.3

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

none

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,130,993 (Gutman et al.) 14 July 1992, cols 1-5.	1-10
Y	US, A, 5,168,497 (Ozaki et al.) 01 December 1992, cols 1-2.	1-10
A	US, A, 5,230,002 (Yamashita et al.) 20 July 1993, cols 4 and 5.	1-10
A	US, A, 4,893,339 (Bright et al.) 09 January 1990, see figure 2.	1-10
A	US, A, 4,779,275 (Yoshimoto) 18 October 1988, see figure 2 and col. 3.	1-10
A	US, A, 4,577,313 (Sy) 18 March 1986, see figure 4 and col. 7.	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

01 DECEMBER 1994

Date of mailing of the international search report

JAN 23 1995

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer
B. Harden for
ROY ENVALL JR.
Telephone No. (703) 305-9706

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